Performance Measures of Hierarchical Cellular Networks on Queuing Handoff Calls

Kashish Parwani[1] and G.N. Purohit[2]
[1] Banasthali University, AIM & ACT, Banasthali, India
Email: kparwani1@yahoo.com
[2] Banasthali University, AIM & ACT, Banasthali, India
Email: gn_purohitjaipur@yahoo.co.in

***Abstract*— Hierarchical Cellular Networks provide an enhanced use of the indoor networks. These two lower layers called picocell and femtocell consist both high and low speed users. To prevent the dropping and blocking probabilities of ongoing calls in a network, cells are spitted into the small sizes. Although, many effective approaches are used but these delaying calls reach in a queue until a channel becomes available. In this paper, we propose M/M/C Markov model for two low layers of HCN having a FIFO queue in the femtocell layer and picocell layer, thereby comparing with a queue and without a queue. The effect of having a queue in the femtocell and picocell on both high and low speed users is observed.**

***Keyword*—Hierarchical Cellular Network (HCN), Blocking Probability, Markov Model, FIFO queue, Two low layer (picocell and femtocell).**

I. Introduction

With the increasing demand of wireless communication service, the hierarchical cellular technology provides a back bone for indoor networks. HCN have four type of layers i.e. macrocell, microcell, picocell and femtocell but our concentration is only on two low layer of HCN i.e. picocell and femtocell. In the past, source of indoor coverage was only provided by an outdoor antenna. And at present the only way to increase indoor coverage is to add more cells and this led to the creation of more small outdoor cells (microcells) providing more capacity for the network. Unfortunately, this approach is expensive for operators because it requires to install more sites, which dramatically increase the maintenance costs.

Finally, the more recent solution is the installation of small indoor base stations like picocells or femtocells. A multitier cellular network can improve the system performance by having larger cells overlaying the smaller cells and high speed users are assigned to the layer with larger cell sized. We propose a model of two tier cellular network with a FIFO queue in the femtocell to study on the both high and low speed users and compare with the result having a queue in the femtocell and having no queue in picocell.

II. Releted Work

Many models have been developed in wireless cellular networks which provide the best performance and efficiency. In [1] proposed the handover call blocking probability in cellular networks with high speed moving terminals. Salih.T, et al. [2] has developed a Markov Model for a two tier cellular network and also compared with previous proposed models. Chandrasekhar, et al.[3] gave femtocell networks a survey which described the features of femtocell. Kudoh.E, et al. [4] studied picocell network for local positioning and information system.

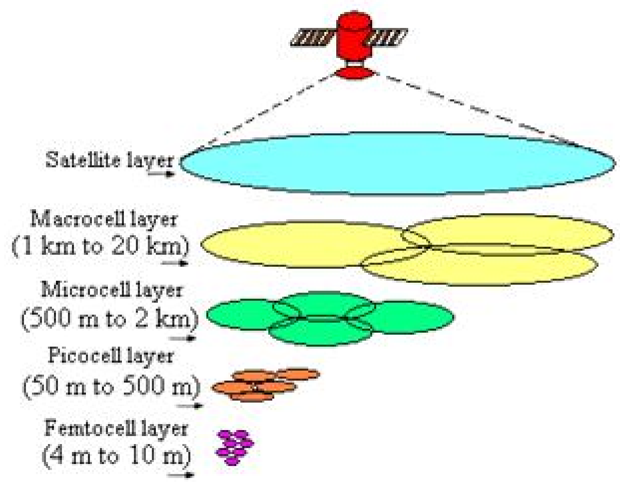

Figure 1. Hierarchical Cellular Structure.

Parwani.K, et al. [19] proposed performance measures of mobile communication networks with hierarchical cellular networks. X.Wu, et. al. [6] compared the performance of two tier cellular networks based on queuing handoff calls. In [10], proposed a combined channel assignment (CCA) mechanism for hierarchical cellular systems with overlaying macro cells and overlaid microcells. Jie Zhang, et. Al., studied femtocell technology and deployment [17]. In July 2007, the femto forum [20] was founded to promote femtocells standardization and deployment worldwide. Parwani. K, et. al. [18] compared the performance of the two low layers of hierarchical cellular networks with four types of schemes: new call bounding scheme, cut off priority scheme with and without sub-rating.

In [14] found out the challenges in the technical and commercial aspects of femtocells for facilitation of the mass deployment of femtocells in the global scenario. Jung-Min.Moon et. al. [15], studied the performance of a combined guard channel and channel reservation with queuing resource management scheme for efficient handing of handoff calls in a macro / femtocell hierarchical cellular network. A bandwidth efficient handoff strategy is proposed [12] and analyzed for hierarchical cellular system.

DOI: 01.IJNS.03.01.528

III. System Description

In this paper, two low layers of HCN with a FIFO queue in the femtocell is proposed. A small geographical area is covered by this proposed model. Low and high speed users are assigned to the femtocells and the picocells, respectively. The radius of the femtocell is smaller than the picocell, and an integer number of femtocells are covered by one picocell. A handoff call is blocked when it cannot find a free channel in the desired cell. This happens due to the queue is full or the queue time assigned to the user is too short, a new call is blocked when it cannot find a free channel in the cell at that time calls will be overflowed. Once a low speed user call is overflowed to the picocell it cannot return back to the femtocell and when a low speed user becomes a high speed user the call is overflowed to the picocell. Calls overflow from the femtocell to the picocell when the low speed user becomes a high speed user and when the low speed user's new and handoff call cannot find a free channel in the femtocell.

IV. MODEL DESCRIPTION

We assume that the cells are circular in shape. Table 1.shows the parameters have used for modeling cellular network. The arrival rates of new calls and handoff calls for both low and high speed users are assumed to be Poisson process. The cell dwelling time is the time a mobile user spends in a cell. It depends on the speed of the mobile user and the size of the cell.

We consider a single cell which present in the network and the picocell covers N number of femtocells and the cells are circular in shape. Each cell has C channels, and FIFO queue size Q in the picocell. The arrival rates of new calls for low and high speed users are Poisson processes with a rate of λ_l and λ_h calls per second respectively. The arrival rate of handoff calls for low and high speed users are Poisson processes with a rate of λ_l and λ_h calls per second respectively. The average holding time ror both types of users is negatively exponentially distributed with a mean of $1/\mu$. The cell dwelling time can be calculated as:

$$\frac{1}{\mu_d} = \frac{\pi r}{2v} \qquad (1)$$

Where r in the radius of the cell and v is the speed of the mobile users. The cell dwelling time for low and high speed users are negatively exponentially distributed with a mean of $1/\mu_{dl}$ and $1/\mu_{dh}$ respectively. In [6], it is shown that the mean queue time depends on two parameters.

i) The mean cell dwelling time

ii) The maximum cross distance M, over the overlapping zone between two cells. Hence queue time = (M/100)*cell dwelling time. We assume that the queue time for low and high speed users is negatively exponentially distributed with a mean of $1/\mu_{ql}$ and $1/\mu_{dh}$, respectively.

TABLE I. Model parameters and descriptions

Symbol	Description
C	Number of channels in each cell
N	Number of Femtocells that are overlaid by one Picocell.
Q	Size of FIFO queue
λ_l	Arrival rate of new calls for low speed users
λ_h	Arrival rate of new calls for high speed users
λ_{hl}	Arrival rate of handoff calls for low speed users
λ_{hh}	Arrival rate of handoff calls for high speed users
$1/\mu$	Mean average holding time for both types of users
$1/\mu_{dl}$	Mean cell dwelling time for low speed users
$1/\mu_{dh}$	Mean cell dwelling time for high speed users
$1/\mu_{ql}$	Mean queue time for low speed users
$1/\mu_{qh}$	Mean queue time for high speed users

V. Analysis of the Femtocell

A. Femtocell layer without queue

A femtocell layer with two types of users and without a queue is analyzed with a state s (i), where i denotes the number of low speed users using the c channels. The state transition diagram is as follows:

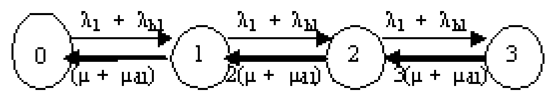

Figure 2. State transition diagram for a femtocell containing 3 channels.

The steady state probability of the system is given by :

$$P(i) = P(0)\frac{(\lambda_l+\lambda_{hl})^i}{(\mu+\mu_{dl})^i\, i!}\,, \quad i \le c \qquad (2)$$

$$\text{since } \sum_{i=0}^{c} P(i) = 1, \text{ then P(0) can be calculated as follows :}$$

$$P(0) = \left[1 + \sum_{i=1}^{c}\left(\frac{(\lambda_l+\lambda_{hl})^i}{(\mu+\mu_{dl})^i\, i!}\right)\right]^{-1} \qquad (3)$$

To find the arrival rate of handoff calls, we use the method in [7] as follows:

$$\lambda_{hl} = \sum_{i=1}^{c} \left(iP(i)\mu_{dl}\right) \qquad (4)$$

The blocking probabilities for the new and handoff calls are the same since no prioritization is used. Both probabilities are used as in [20] to calculate the overflow traffic to the picocell. The new call blocking probabilities for low speed users in the femtocell, P_n is given by

$$P_n = \sum_{i=c}^{c} P(i) = \mathrm{P(c)} \qquad (5)$$

DOI: 01.IJNS.03.01.528

B. Femtocell layer with queue:

Fig (3) shows the state s(i), where i denotes the number of low speed users in the femtocell and represented by a Markov Chain with FIFO queue. We assume that the number of channels, C=3 and the queue size Q=3;

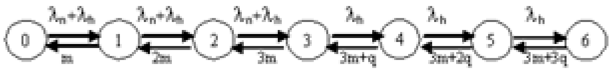

Figure 3. State transition diagram for a femtocell with 3 channel and a queues size 3.

In the above transition diagram, *m* and q are given by $m=\mu+\mu_{dl}$ and $q=\mu+\mu_{ql}$, respectively.
By solving the Markov chain; we find that the state prob.P (i) :

$$P(i)=\begin{cases} P(0)\dfrac{(\lambda_{1n}+\lambda_{ih})^{i}}{i!(\mu+\mu_{dl})^{i}} & i\le c \\ P(0)\dfrac{(\lambda_{1n}+\lambda_{ih})^{c}\lambda_{ih}^{i-c}}{c!(\mu+\mu_{dl})^{c}\prod_{j=1}^{i-c}\left[c(\mu+\mu_{dl})+j(\mu+\mu_{ql})\right]} & i>c \end{cases} \tag{6}$$

Since $\sum_{i=0}^{c} P(i)=1$, then P (0) can be expressed as;

$$P(0)\left[1+\sum_{i=1}^{c}\frac{(\lambda_{1n}+\lambda_{1h})^{i}}{i!(\mu+\mu_{dl})^{i}}+\sum_{i=c+1}^{c+Q}\frac{(\lambda_{1n}+\lambda_{1h})^{c}\lambda_{1h}^{i-c}}{c!(\mu+\mu_{dl})^{c}\prod_{j=1}^{i-c}\left[c(\mu+\mu_{dl})+j(\mu+\mu_{ql})\right]}\right]^{-1} \tag{7}$$

The blocking probability for new calls, P_n, is given by

$$P_n=\sum_{i=c}^{c+q}P(i) \tag{8}$$

The blocking probability for new calls, P_h, is given by

$$P_h=\sum_{i=c+Q}P(i) \tag{9}$$

The overflow traffic for low speed new calls, λ_{ol} and handoff call, λ_{olh} are calculated using following equations.

$$\lambda_{o1}=N\lambda_{1}P_{n},\ \lambda_{01h}=N\lambda_{h1}P_{n} \tag{10}$$

VI. Analysis of the Picocell

In this section, the analysis corresponds to the picocell layer without queue. Fig (4) shows the state *s(i,j) where i and j* are the number of low and high speed users in the system and Markov chain model with 3 channels is shown in figure 3.

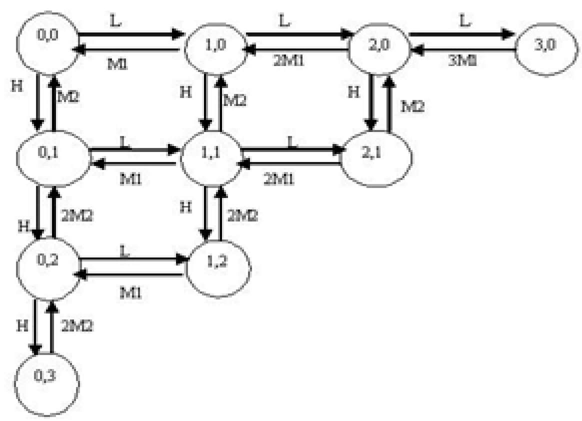

Figure 4. Markov model of the picocell with 3 channels.

The parameters involved in the Markov chain are defined as follows:

$$L=\lambda_{01}+\lambda_{01h}+\lambda_{L2,}$$
$$H=\lambda_{h}+\lambda_{hh}$$
$$M1=\mu+\mu_{dl}$$
$$M2=\mu+\mu_{dh}$$

To find the equilibrium eq. of the state probabilities using [9],

$$\alpha(i,j,q)=\begin{cases}1 & i+j<c\\ 0 & \text{else}\end{cases}$$
$$\beta(i,j,q)=\begin{cases}1 & i\neq 0\\ 0 & \text{else}\end{cases}$$
$$\delta(i,j,q)=\begin{cases}1 & j\neq 0\\ 0 & \text{else}\end{cases}$$

The equilibrium eq. for the state occupancy probabilities *P(I,j,q)* can be calculated as follows:

$$(\alpha(i,j)(L+H)+\beta(i,j)iM1+\delta(i,j)jM2)P(i,j)= \alpha(i,j)(P(i,j+1)(j+1)M2+P(i+1,j)(i+1)M1)+ \beta(i,j)P(i-1,j)L+\delta(i,j)P(i,j-1)H \tag{11}$$

The blocking probability for new calls, P_{bn}. in the picocell is given by

$$P_{bn}=\sum_{i+j=c}P(i,j) \tag{12}$$

Since, the picocell does not have a queue, the blocking probability for handoff calls, P_{bh}, in the picocell can be calculated using the same equation for $P_{bh.}$

VII. Results & Discussion

In this section, we describe the numerical results for the two low layers of HCN. We propose the M/M/C Markov model and compare the results with and without a queue in the femtocell and without a queue in the picocell. We assume that one picocell covers N=7 femtocells and each cell contains3 Channels. Speed of the low mobile users is 1m/s and high mobile users are 10 m/s. The cell size of the picocell

DOI: 01.IJNS.03.01.528

is larger than the femtocell and radius of the femtocell = 2 meters and the picocell 10 meters. The maximum cross distance of the overlapping zone between two cells is 13% of the diameter of a cell. Queue time qt=3x0.13=0.39 sec ≈ 0.4 sec. The cell dwelling time = 3x√7 =7.8 ≈ 8 sec. Fig.5. shows that the model with a queue in the femtocell layer has higher blocking probability then the others because it has a queue and other two are having lower blocking probability because they have no queue. Fig.6 shows that the blocking probability for handoff call is increases due to having a queue in femtocell and decreases as there is no queue in femtocell and picocell.

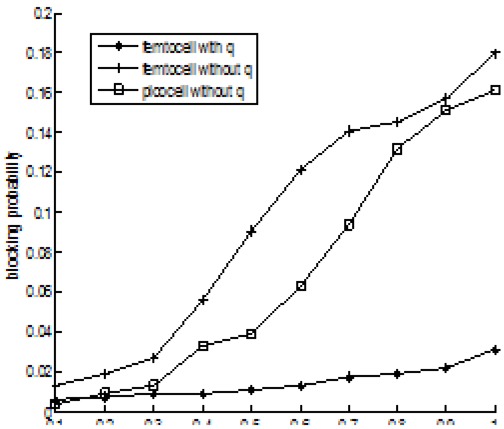

Figure 5. Blocking probability of new calls

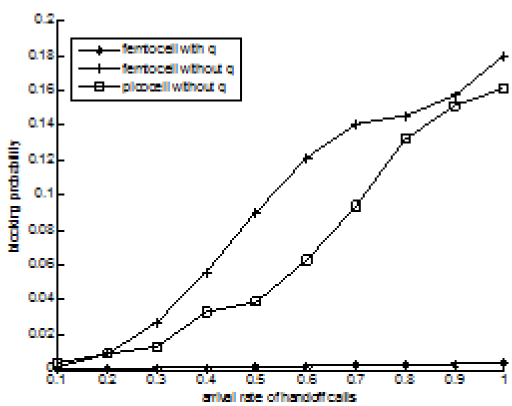

Figure 6. Blocking probability of handoff calls

TABLE II. BLOCKING PROBABILITY OF NEW CALLS

λ_n	P_n (Femtocell without q)	P_n (Femtocell with q)	P_n Picocell (without q)
0.1	0.0059	0.0130	0.0040
0.2	0.0073	0.0190	0.0093
0.3	0.0089	0.0272	0.0132
0.4	0.0091	0.0560	0.0333
0.5	0.0111	0.0903	0.0390
0.6	0.0129	0.1212	0.0630
0.7	0.0174	0.1406	0.0941
0.8	0.0191	0.1454	0.1320
0.9	0.0221	0.1573	0.1510
1.0	0.0311	0.1801	0.1610

TABLE III. BLOCKING PROBABILITY OF HANDOFF CALLS

λ_h	P_h (Femtocell without q)	P_h (Femtocell with q)	P_h Picocell (without q)
1	0.0001	0.0013	0.0040
2	0.0003	0.0090	0.0093
3	0.0009	0.0272	0.0132
4	0.0011	0.0560	0.0333
5	0.0014	0.0903	0.0390
6	0.0019	0.1212	0.0630
7	0.0024	0.1406	0.0941
8	0.0029	0.1454	0.1320
9	0.0035	0.1573	0.1510
10	0.0040	0.1801	0.1610

CONCLUSION

In this paper, we proposed a Markov Model for a two low layers (picocell and femtocell) of hierarchical cellular network with a FIFO queue. We considered the cell size, the cell dwelling time and the mobility of users to calculate the queue times of both types of users. We have proved that by having a queue of the handoff call blocking probability is reduced. The performance of the proposed model shows that having a queue in one of layer of the cellular network depends on the distribution of the users in the geographical area of the network.

REFERENCES

[1] K Ioannou, S. Louvros, "Optimizing the handover call blocking probability in cellular networks with high speed moving terminals. IEEE Communications letters, VOL6, No.10, Oct 2002.

[2] Tara Salih, Kamal M Fidanboyiu, "Performance Analysis and Modeling of tier cellular networks with queuing handoff calls, IEEE international symposium on computers and communication (ISCC'03) 2003.

[3] V. Chandrashekhar and J.C. Andrews, "Femtocell networks, A survey". IEEE communication magazine, Vol.46, no.49, pp59-67, sep2008.

[4] E Kudoh, A.Shibuja, S. Kobotu, 'Pico cell network for local positioning and information system, 'in 26th annual conference of tha IEEE industrial Electronic society. Vol.2, Oct2000, pp.1165-1170.

[5] Tara Salih and Kemal Fidanbouh, "A comparison of the comparison of the performance of two tier cellular networks based on querying handoff calls, International journal of applied mathematics and computer sciences Feb 2006.

[6] Wu, X. "Supporting quality of services (Qos) in overlaid wireless networks, PhD. thesis; University of California Davis, USA 2001.

[7] L.Hu and S.S. Rappaport, "Personal communication systems using multiple hierarchical cellular overlays", IEEE Journal selected areas in communications, 13(2), 406-415, Feb 1995.

[8] M. Chiu and M.A Bassioni, "Predictive schemes for handoff prioritization in cellular networks based on mobile positioning". IEEE on selected area in communications, Vol. 18, No. 3, March 2000.

[9] X.Liu, A.O. Fapojuwo, "Resource management for handoff traffic in hierarchical cellular networks". 24th IEEE international, Performance, computing, and communications conference, 2005. IPCCC.

DOI: 01.IJNS.03.01.528

ACEEE

[10] R.K. Jain and N.K. Agrawal, "Hierarchical cellular structures in high capacity cellular communication systems." IJACSA International Journal of Advanced Computer Science and Application, Vol2. No.9, 2011.

[11] S.S.Prasad and R. Baruah. "Femtocell mass deployment Indian perspective". ASID'09 Proceedings of the 3rd international conference on Anti-Counterfeiting, security, and identification in communication IEEE Press Piscataway, NJ, USA ©2009

[12] Boli, Chenke Wu and Fujuda. A, "Performance analysis of flexible hierarchical cellular systems with a bandwidth efficient handoff schemes". Vehicular Technology, IEEE transactions on Vol. 50, issue 4, P.P. 971-980, 2001.

[13] Shung-Ping Chung and Min-Tsang Li, "Performance of hierarchical cellular CDMA networks with soft handoff queuing". Vehicular technology, IEEE transactions on vol.54, pp.652-672, 2005.

[14] Wu, X.,Zheng, J., Regantova, E.Jiang, Y."Analysis of the effect of channel sub-rating in unidirectional call overflow scheme for call admission in hierarchical cellular networks". Vehicular Technology Conference, VTC 2007-Spring, pp. 1265-1269, 2007.

[15] Jung-Min Moon and Dong-Ho Cho, "Efficient handoff algorithm for inbound mobility in hierarchical macro/femtocell networks". Communications Letters, IEEE Vol. 13, issue 10, pp. 755-757, Oct 2009.

[16] A book "Femtocell Primer" by David Chambers (2008).

[17] Jie Zhang and et al.,"Femtocells technologies and deployment". A John Wiley and Sons, Ltd, publication (2010).

[18] K. Parwani, G.N. Purohit and Geetanjali Sharma, "Performance evaluation of mobile communication in a hierarchical cellular system with different schemes", CIIT 2011.CC IS 250 pp.677-683, Springer- Verlag Berlin Heidelberg .

[19] K. Parwani and G.N. Purohit, "Performance measures of mobile communication networks with hierarchical cellular networks IEEE international conference (ICCDe-com) 2011.

[20] E. Ekici, C. Ersoy, "Multi-tier cellular network dimensioning", wireless network 7, 401-411, 2001.

[21] www.femtoforum.org.

[22] http://www.Thinkfemtocell.com.

DOI: 01.IJNS.03.01.528